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STANDARD METHOD OF GRAPHICAL PRESENTATION OF CENTRIFUGAL COMPRESSOR PERFORMANCE

By NACA Subcommittee on Supercharger Compressors

Aircraft Engine Research Laboratory
Cleveland, Ohio

NACA

WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE RESTRICTED REPORT

STANDARD METHOD OF GRAPHICAL PRESENTATION OF CENTRIFUGAL COMPRESSOR PERFORMANCE

By NACA Subcommittee on Supercharger Compressors

SUMMARY

The NACA Subcommittee on Supercharger Compressors has recommended the use of the method described in this report, for comparing the performance of centrifugal compressors, and it has been adopted by the NACA as a standard.

INTRODUCTION

Recognizing that a standard method for presenting supercharger performance would be very convenient when comparing test results, the NACA Subcommittee on Supercharger Compressors appointed a special panel, which first met in October 1944, to study this problem. The members of this panel were as follows:

Lieutenant Commander John Marchant, U.S.N.R., chairman
Mr. Harold Klein[a]
Mr. John Talbert[b]
Mr. W. S. Thompson[c]

The membership of the NACA Subcommittee on Supercharger Compressors during the time of the preparation of the present report was as follows:

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[a]Mr. Klein was not a member of the subcommittee, but was appointed to serve on the panel and was assigned to prepare the various drafts of the report through the cooperation of Mr. Oscar W. Schey.
[b]Mr. Talbert was not a member of the subcommittee during 1944, but was appointed to serve on the panel through the cooperation of Mr. Campbell.
[c]Mr. Thompson was not a member of the subcommittee during 1944, but was appointed to serve on the panel through the cooperation of Mr. King.

Mr. Kenneth Campbell, chairman
Mr. Rudolph Birmann
Lieutenant Commander William Bollay, U.S.N.R.
Mr. Opie Chenoweth
Mr. Walter Doll[d]
Professor Howard W. Emmons
Commander W. T. Hines, U.S.N.
Mr. W. J. King[e]
Lieutenant Commander John Marchant, U.S.N.R.
Mr. E. A. Poste[e]
Mr. Arnold H. Redding[d]
Dr. J. T. Rettaliata
Mr. Oscar W. Schey
Mr. John Stack
Mr. John Talbert
Mr. W. S. Thompson

References 1, 2, and 3 are of general interest in connection with the problem discussed in the present report.

DISCUSSION

The most convenient method of graphical presentation of the performance of compressors is, of course, dependent on what use is to be made of the results. The principal use of the graphs presented herein will be for comparison of superchargers with each other and for predicting supercharger performance for specific applications. The manner of plotting supercharger data must permit the application of results to various conditions of inlet temperature and pressure. The use of uncorrected tip speeds, rotational speeds, weight flow, or volume flow is basically unsound. The selection of a particular dimensionless or corrected-dimensional method is largely a matter of convenience. The dimensionally corrected methods will give a better physical picture of the tip speed and size of the unit than will the dimensionless methods. The most important dimensionless indices of performance of compressors are:

η_{ad} adiabatic temperature rise ratio or adiabatic efficiency

η_s adiabatic shaft efficiency

p_{2t}/p_{1t} pressure ratio

The above indices are functions of the following parameters: flow quantity, Mach number or tip speed, Reynolds number, heat

[d]Not members of the subcommittee during 1944.
[e]Not members of the subcommittee during 1945.

transfer, and relative impeller clearance. The first two parameters are the most important and the remaining three are usually of minor importance. The performance is, therefore, graphically presented in terms of the first two parameters, and information is given as to what conditions of the second group of parameters were maintained during the tests.

The method of presentation recommended after due consideration of the various forms of the parameters available is illustrated in figure 1. The ordinate selected is the dimensionless ratio of the absolute total pressures p_{2t}/p_{1t} plotted on a uniform scale. The abscissa selected is a flow-quantity parameter $Q_{1t}/\sqrt{\theta}$ corrected to standard sea-level conditions or

$$\frac{Q_{1t}}{\sqrt{\theta}} = \frac{WR\ T_{1t}}{\sqrt{\theta}\ p_{1t}} \tag{1}$$

where

Q_{1t} volume flow at inlet stagnation conditions, cubic feet per minute

W weight flow of air, pounds per minute

R gas constant for normal air (53.50)

T_{1t} inlet stagnation temperature, $^{\circ}F$ absolute

p_{1t} absolute inlet stagnation pressure, pounds per square foot

θ ratio of actual inlet stagnation temperature to standard sea-level temperature $(T_{1t}/518.4)$

An additional abscissa $Q_{1t}/\sqrt{\theta}\ D_2^{\ 2}$ is also provided to permit the comparison of various size compressors on the same basis. Large values of $Q_{1t}/\sqrt{\theta}\ D_2^{\ 2}$ indicate a large specific capacity, where D_2 is impeller diameter in feet (largest diameter if multistage).

The Mach number or tip-speed parameter is $U/\sqrt{\theta}$, tip speed in feet per second corrected to sea-level conditions, where U is impeller tip speed in feet per second. Maximum tip speed is selected for multistage centrifugal compressors in which the various stages may have different tip speeds.

Experimental points should be indicated to permit an estimate of precision of the data and contours of adiabatic efficiency should be superimposed on the pressure-ratio curves. In order to plot these contours of constant efficiency at suitable intervals a cross-plot such as figure 2 may be constructed from which the contours can be readily filled in. Adiabatic temperature-rise efficiency shall be plotted in this manner. Where laboratories have facilities for power input measurements, an additional plot of figure 1 on an adiabatic shaft efficiency basis shall be included.

It is useful to the user and designer of centrifugal compressors to prepare plots on uniform scale coordinates of: (a) pressure coefficient versus Q_{1t}/n, where n is angular velocity of impeller in revolutions per second and (b) adiabatic temperature rise ratio versus $Q_{1t}/\sqrt{\theta}$; and it should be pointed out that the presentation of the basic curves of figure 1 does not preclude submission of plots of the preceding or additional graphic data.

Heat-transfer or viscosity effects may affect the performance although these effects are generally of small importance. In order to indicate this heat-transfer effect, the inlet temperature at which each tip speed was run should be specified on the curve in tabular form on the curve sheet. (See fig. 1.)

The following information shall be provided on the curve sheet illustrated by figure 1.

Impeller outside diameter, feet

Impeller inlet diameter, feet

Inlet annulus area, square feet

Clearance (running clearance preferred) between open face of impeller and casing, inches

Inlet or outlet pressure, whichever is held constant during test, inches of mercury absolute

Mach number at point of outlet pressure measurement at maximum efficiency condition for each tip speed

RECOMMENDATIONS

The method of plotting pressure ratio against the quantities $Q_{1t}/\sqrt{\theta}$ and $Q_{1t}/\sqrt{\theta}D_2^{\,2}$ with adiabatic-efficiency contours on

uniform scale coordinates is deemed most suitable for presentation of compressor performance and is recommended as a standard except in cases where there is a specific reason for using another method of presentation. It is also recommended that the supplementary information be given in the form indicated.

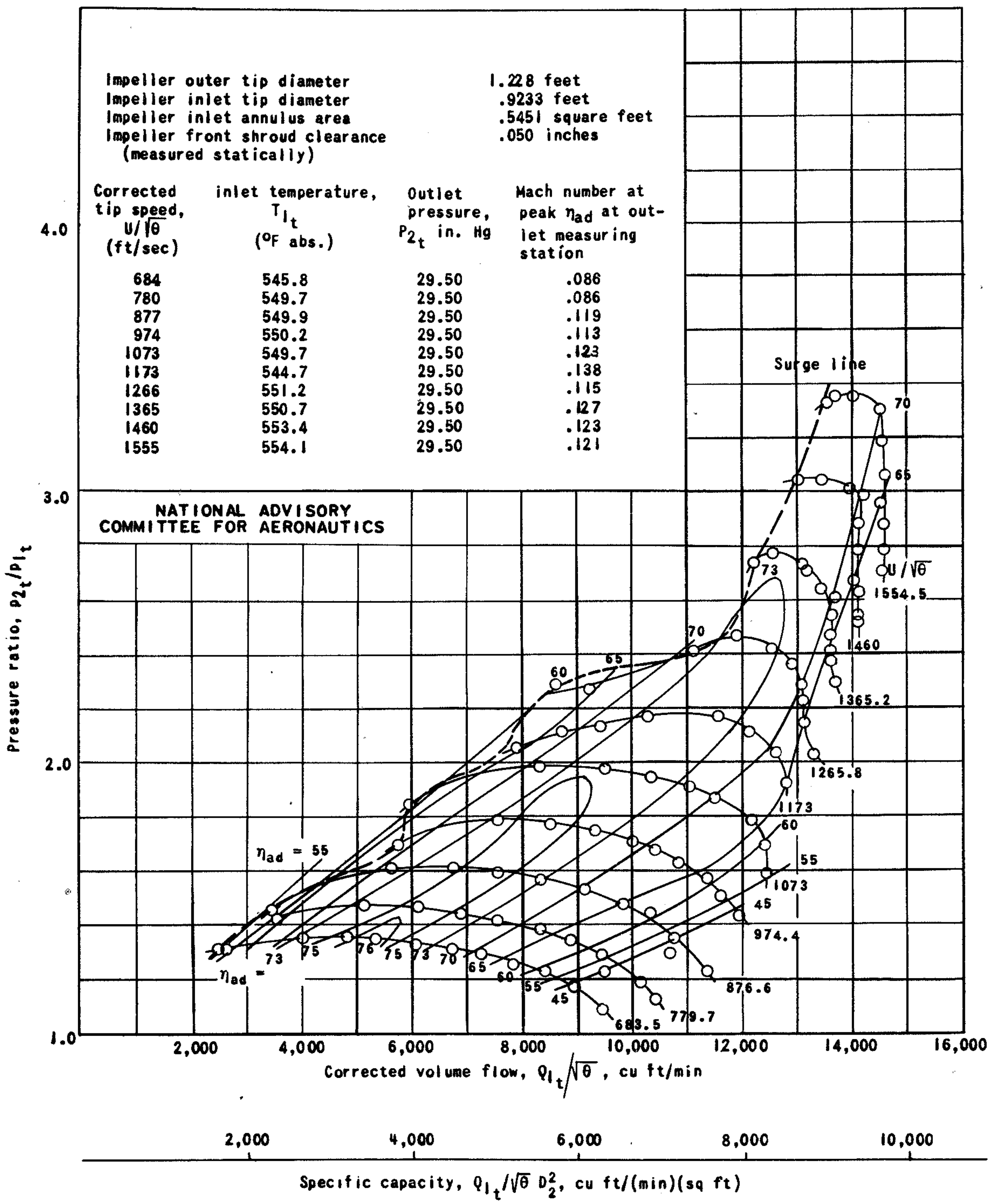
National Advisory Committee for Aeronautics,
Washington, D. C., June 13, 1945.

REFERENCES

1. NACA Subcommittee on Supercharger Compressors: Standard Procedures for Rating and Testing Centrifugal Compressors. NACA ARR No. E5F13, 1945.

2. Ellerbrock, Herman H., Jr., and Goldstein, Arthur W.: Principles and Methods of Rating and Testing Centrifugal Superchargers. NACA ARR, Feb. 1942.

3. Capon, R. S., and Brooke, G. V.: The Application of Dimensional Relationships to Air Compressors, with Special Reference to the Variation of Performance with Inlet Conditions. R. & M. No. 1336, British A.R.C., 1930.



Corrected tip speed, $U/\sqrt{\theta}$ (ft/sec)	Inlet temperature, T_{1_t} (°F abs.)	Outlet pressure, P_{2_t} in. Hg	Mach number at peak η_{ad} at outlet measuring station
684	545.8	29.50	.086
780	549.7	29.50	.086
877	549.9	29.50	.119
974	550.2	29.50	.113
1073	549.7	29.50	.123
1173	544.7	29.50	.138
1266	551.2	29.50	.115
1365	550.7	29.50	.127
1460	553.4	29.50	.123
1555	554.1	29.50	.121

Figure 1. - Recommended method of presenting compressor performances

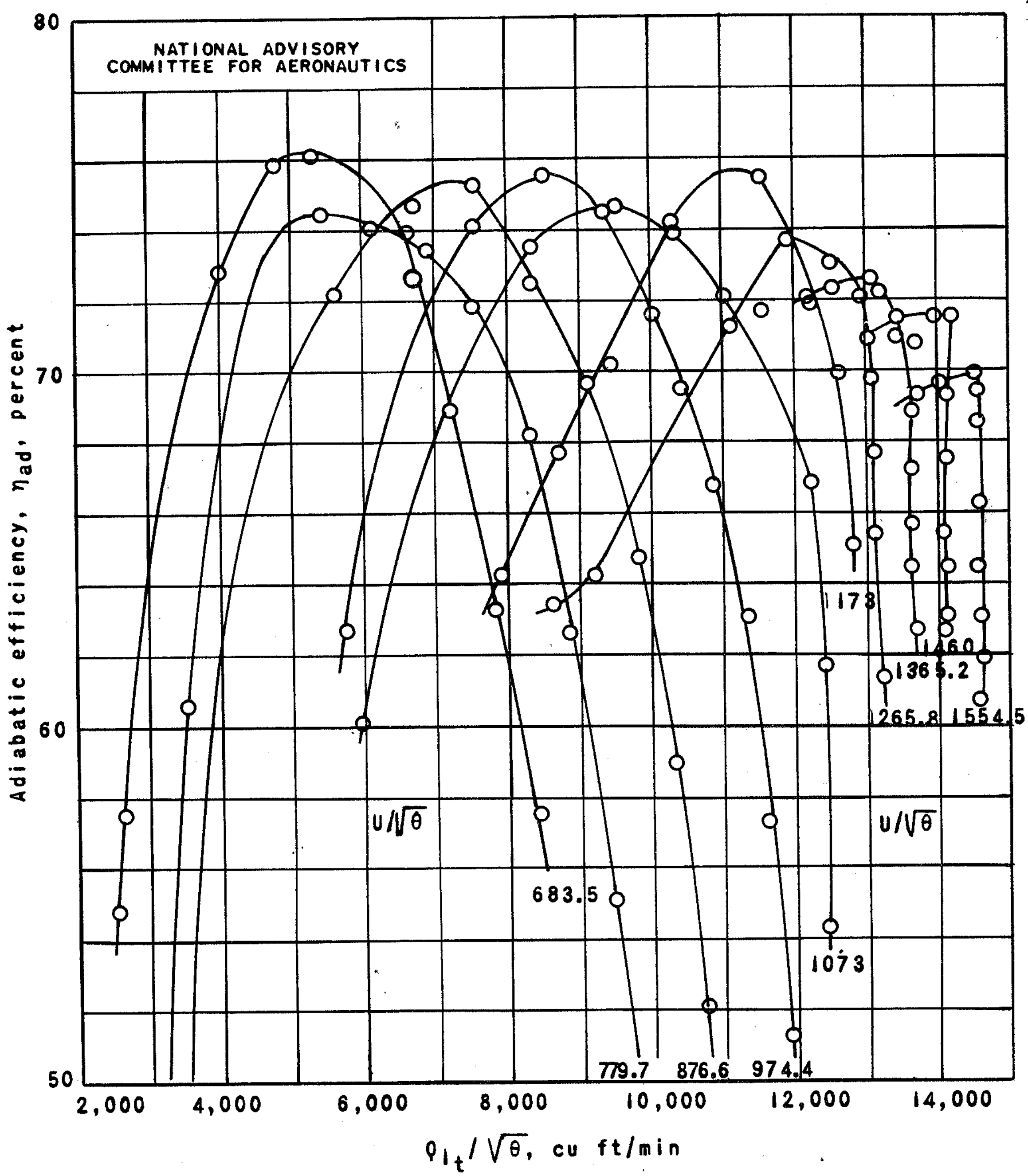


Figure 2. - Cross plot of efficiencies for drawing contours.